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9500563 23 March 1995 (23.03.95) NL(71) Applicant (for all designated States except US): NED-  
ERLANDSE ORGANISATIE VOOR TOEGEPAST-  
NATUURWETENSCHAPPELIJK ONDERZOEK TNO  
[NL/NL]; Schoemakerstraat 97, NL-2628 VK Delft (NL).

(72) Inventors; and

(75) Inventors/Applicants (for US only): BAERT, Rik, Silveer,  
Geert [BE/BE]; Draaiboornstraat 45, Bus 2, B-2160  
Wommelgem (BE). BECKMAN, Derek, Edward [NL/NL];  
Meester Willemstraat 36, NL-3036 MN Rotterdam (NL).  
VERBEEK, Rudolfus, Petrus [NL/NL]; Gerbrandystraat 67,  
NL-2672 BK Naaldwijk (NL).(74) Agent: DE BRUIJN, Leendert, C.; Nederlandsch Octrooibu-  
reau, Scheveningseweg 82, P.O. Box 29720, NL-2502 LS  
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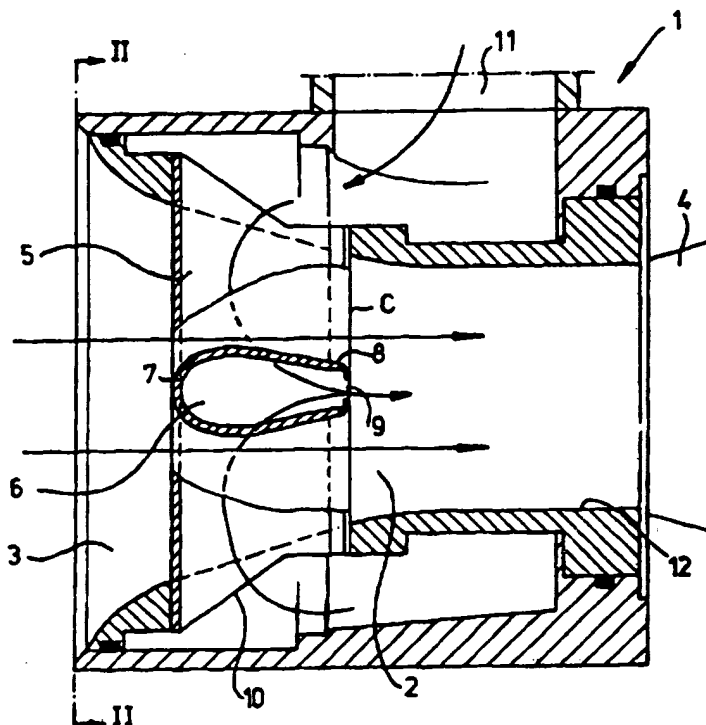
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(54) Title: VENTURI MIXING APPARATUS

## (57) Abstract

Venturi mixing apparatus consisting of a venturi having a main stream duct. Means for metering a secondary fluid into the main stream are present in the main stream duct. These means comprise a bar element, being firmly fixed, the upstream end of the bar element being provided with an opening for feeding in the secondary fluid. The bar element is arranged at least partially in the convergent inlet section of the venturi.



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## Venturi mixing apparatus

The present invention relates to venturi mixing apparatus according to the preamble of claim 1.

5 A venturi mixing apparatus of this type is generally known in the prior art. This venturi mixing apparatus is used for mixing, for example, air and a gas. In this context the gas can be a gaseous fuel and/or a exhaust gas which is recycled to, for example, a combustion engine. It is likewise possible  
10 to feed solid particles into a gas stream with the aid of a fluid of this type, the solid constituents being carried in the secondary fluid.

However, it must be understood that the invention relates to venturi mixing apparatus for every application where optimum  
15 mixing is important.

Other methods for mixing a secondary fluid with a main fluid in a venturi comprise making a series of openings or an annular opening in the wall of the venturi. Said openings are, in general, also made in the vicinity of the throat. Reference  
20 is made to DE-U-8634567 in the name of the Applicant.

There are at least three requirements when mixing a secondary fluid into a main fluid by means of a venturi mixing apparatus. Firstly, the aim is for adequate suction for the secondary fluid, which is achieved by means of a constriction  
25 in the main flow duct. Secondly, the aim is for optimum, that is to say rapid and homogenous, mixing of the secondary fluid into the main fluid, whilst, on the other hand, the aim is for minimum pressure loss in the main stream.

The pressure loss in the main stream over the mixer is a  
30 consequence of frictional losses in the main stream (at the wall of the venturi and of the bar element), of transfer of momentum from the main fluid to the secondary fluid and of the conversion of kinetic energy (dynamic pressure) into turbulent eddies on separation of the flow as a consequence of too great  
35 a divergence in the flow duct.

In order to restrict the pressure loss as much as possible with optimum mixing, it is proposed in the publication entitled 'New Gas Mixer for Gas Engines, SAE paper 922361', to make the

outflow openings for the secondary fluid in the divergent downstream section of the wall of the venturi.

In the case of this apparatus the position at which the secondary fluid is fed in counteracts the separation of the main stream (in the divergent part of the venturi), with, as a result, less turbulence (and less pressure loss) and consequently severely delayed mixing. Moreover, the introduction of secondary fluid does not take place uniformly distributed over the main fluid.

10 The aim of the present invention is to provide a venturi mixing apparatus with which, coupled with adequate suction and good mixing, the pressure loss of the main stream in the venturi is restricted as far as possible.

15 This aim is achieved in the case of a venturi mixing apparatus described above having the characterising features of claim 1.

In apparatus according to the prior art, the bar element was located in the narrowest section, the throat, of the venturi. This gave rise to appreciable obstruction of the flow.

20 The invention is based on the insight that adequate suction has to be generated by means of adequate constriction at the location of the gas feed.

Furthermore, the mixing process of two fluids (in a venturi mixing apparatus) proceeds in three steps:

25 1: In the first step the secondary fluid is fed as uniformly as possible into the main fluid. This can be achieved by means of the abovementioned bar element. The stream of secondary fluid is split into a number of partial streams via the outflow openings in the bar element. By distributing the positioning of these openings uniformly over the main stream duct, a uniform macroscopic distribution of secondary fluid over main fluid is achieved.

30 2: In a second step the partial streams of secondary fluid are broken up and distributed over the main stream by turbulence (in the main stream) at the location of and/or downstream of the feed. By means of the two abovementioned steps, the two fluids are mixed in as short as possible a

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space of time in an order of scale of the smallest turbulent eddies.

3: As the third and final step, mixing takes place by molecular diffusion processes.

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According to the invention, it is ensured that turbulent eddies, and thus pressure loss, occur only where secondary fluid is fed into the main stream; this is downstream of the outflow opening. To prevent upstream separation of the main  
10 flow, the cross-section of the mixer must converge up to this point, or must not display more than the abovementioned critical value of divergence. After all, a convergent cross-section leads to an acceleration of the flow and to stable boundary layers.

15 It is possible to construct the convergence of the venturi at the inlet section and the tapering of the bar element up to the feed for the secondary fluid in such a way that the local free flow surface is a) convergent or b) first convergent and then constant or c) first convergent and then slightly  
20 divergent. This divergence must, however, remain below the critical value at which the flow separates from the wall of the venturi and/or of the bar element.

With a view to a uniform feed of secondary fluid over the main stream, the cross-section of the bar element must be  
25 sufficiently large with respect to the outflow surface for the secondary fluid. Together with the requirement for convergence of the cross-section of the mixer (as far as the point of outflow of secondary fluid), this signifies that after an initial rapid increase the cross-section of the bar element  
30 then decreases in the direction of flow. The sudden change in cross-section at the end section of the bar element (which largely determines the pressure loss) is thus as small as possible.

The bar element can have any shape known from the prior art  
35 and can, for example, be of cylindrical construction.

Preferably, this element is so constructed that, after a widened upstream section, the bar element converges in the direction of flow.

The opening or openings in the bar element can be made laterally, as in the prior art, that is to say extend radially with respect to the main stream of fluid.

Preferably, this opening or these openings are made in the  
5 end section and extends or extend in the axial direction in the direction of the main flow of fluid. As a result, the outflow losses of the secondary fluid and undesirable disruption of the flow of the main fluid are particularly limited. On the other hand, adequate turbulence is produced in the vicinity of the  
10 end section in order to provide for optimum mixing of the secondary fluid.

The bar element can comprise one or more bar elements, which may or may not cross one another.

As indicated above, the bar element can have any shape  
15 which is acceptable from the standpoint of flow technology. For instance, it is possible to provide the upstream section of the bar element with a convex shape.

Preferably, the end portion where the gas feed of secondary fluid takes place, is located in the vicinity of the narrowest  
20 section of the venturi at the end of the convergent section because the suction is greatest at this point.

The invention will be explained in more detail below with the aid of an illustrative embodiment shown in the drawing. In the drawing:

25 Fig. 1 shows, diagrammatically, in cross-section, a preferred embodiment of the invention;

Fig. 2 shows a cross-section along the line II-II in fig. 1 and

Fig. 3 diagrammatically the difference between the venturi  
30 according to the prior art and the subject application.

The apparatus according to the invention is indicated in its entirety by 1 in fig. 1. This apparatus comprises a main stream duct 2 consisting of an inlet section 3, which is of convergent construction, a cylindrical section 12 and an outlet  
35 section 4, which is of divergent construction. Although in the embodiment shown between the convergent and divergent section a cylindrical section 12 is introduced, it is possible to omit this section. The venturi 1 is constructed so as to provide an

annular distribution duct, which is connected to a feed 11 for a secondary fluid. Openings 10 are made in the wall of the convergent section 3, which openings are in connection with a bar element consisting of bar elements 5, 6, which are fixedly  
5 secured to the venturi. These bar elements have an upstream section 7 which is convex at the front and from there taper conically and terminate in a slit-shaped opening 9. This opening 9 is located in the vicinity of the narrowest section of the venturi and is made in end section 8. This opening 9 can  
10 be replaced by a series of holes.

Secondary fluid issuing from feed opening 11 moves through the space inside the venturi and opening 10 in the bar elements 5, 6 and then flows out at 9 into the main fluid in order to be mixed with the latter.

15 To prevent separation of the flow, the cross-sectional surface area C of the main stream at the location of the bar elements, between sections 7 and 8, must preferably be convergent or must no longer diverge at a critical value.

Although the free cross-sectional surface area is  
20 preferably smallest at the location of the outflow opening for the secondary fluid in order to obtain a maximum suction effect, it is possible for a smaller cross-sectional surface area to be encountered upstream. In this context it is essential that the divergence is not such that the flow  
25 separates.

In fig. 3 diagrammatically the difference is shown between the pressure drop realised with the venturi according to the invention and with the venturi according to the prior art. In this graph the pressure drop over the venturi is plotted

30 against the mass flow parameter  $\dot{m} \sqrt{\frac{T}{P}}$ . From this graph it is

clear that with the venturi according to the prior art adding more secondary fluid increases the pressure drop. The single line of the venturi according to the subject invention is valid for the range in which between 0 and 10% secondary fluid  
35 (referred to the main fluid) is added. From this graph it is

clear that the new venturi is not sensitive for adding of secondary fluid within a restricted range of secondary fluid. Furthermore it is clear that the pressure drop is considerably reduced with regard to the pressure drop of the venturi  
5 according to the prior art.

Although the invention has been described above with the aid of a preferred embodiment, it must be understood that numerous modifications can be made thereto, which are obvious to a person skilled in the art, without going beyond the scope  
10 of the claims.

For instance, it is possible to construct the venturi in any manner known from the prior art. Furthermore, the bar element can comprise a single element or more than two elements, which may or may not cross one another. The shape of  
15 each bar element can be modified according to need and does not necessarily have to be convergent in the direction of flow from the upstream section.



Claims

1. Venturi mixing apparatus (1) comprising a venturi having a main flow duct (2) with at least one inlet section (3) 5 converging in the direction of flow of the main fluid and a subsequent divergent outlet section (4), means being present in the venturi for supplying a secondary fluid, which has to be mixed with the main fluid, which means comprise a bar element (5, 6) being firmly secured to the venturi, at least part of 10 said bar element extending into the main stream duct, characterised in that that part of the bar element which extends into the main stream duct comprises a widened upstream section (7) which extends in the direction of flow of the main fluid to a downstream end section (8), the region located 15 between the upstream section and the end section being arranged at the location of the convergent inlet section of the venturi.

2. Apparatus according to Claim 1, wherein the upstream section (7) tapers to the end section (8) which is of narrowed construction.

20 3. Apparatus according to one of the preceding claims, wherein the bar element is provided at the end section with at least one opening (9) which extends essentially in the direction of flow of the main fluid and which is in connection with the feed (11) for the secondary fluid.

25 4. Apparatus according to one of the preceding claims, wherein the bar element comprises a number of bar elements (5, 6) crossing one another.

5. Apparatus according to one of the preceding claims, wherein the upstream section (7) has a convex shape.

30 6. Apparatus according to one of the preceding claims, wherein the free flow surface (C) in the vicinity of the end section of the main duct is smaller than at any location upstream thereof.

35 7. Apparatus according to Claim 7, wherein the free flow surface (C) in the vicinity of the end section of the main duct is smaller than or equal to that at any location upstream thereof.

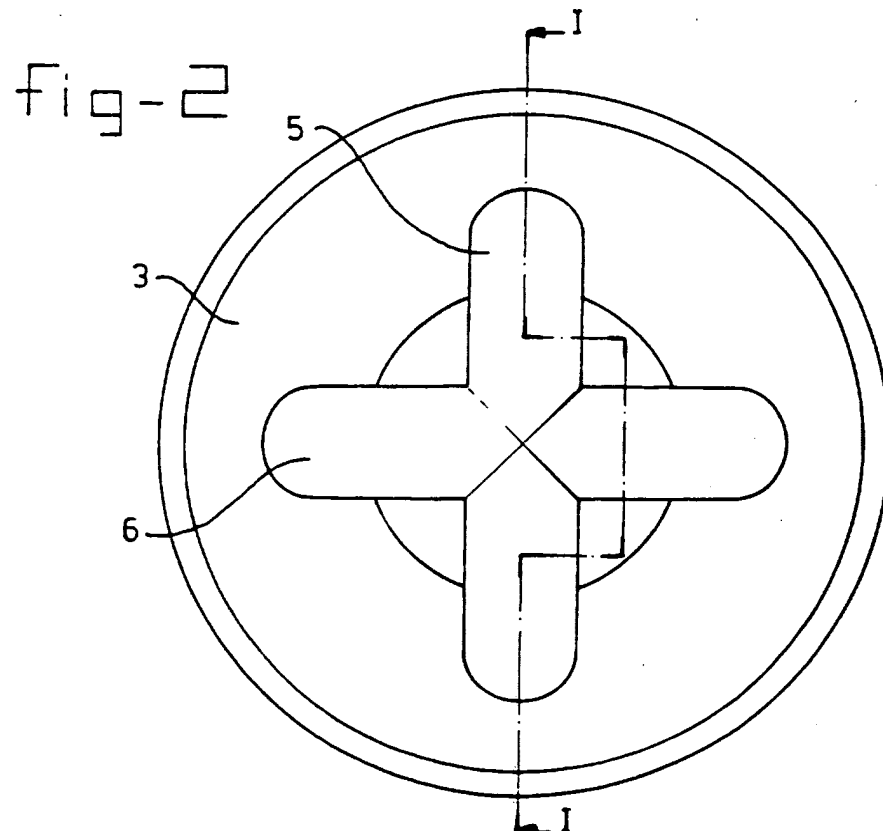
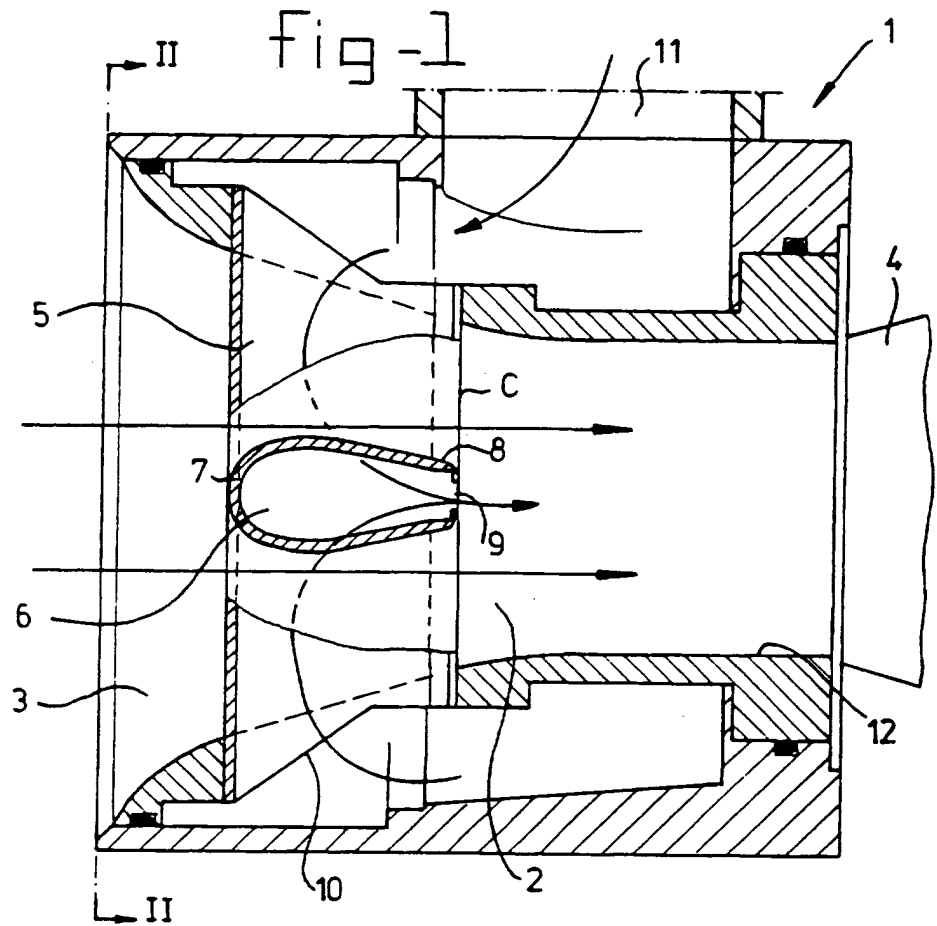
8. Apparatus according to one of the preceding claims 1-5,

wherein the free flow surface (C) in the vicinity of the end section is at least equally as large as the free flow surface in the region between the end section and the upstream section of the bar element.

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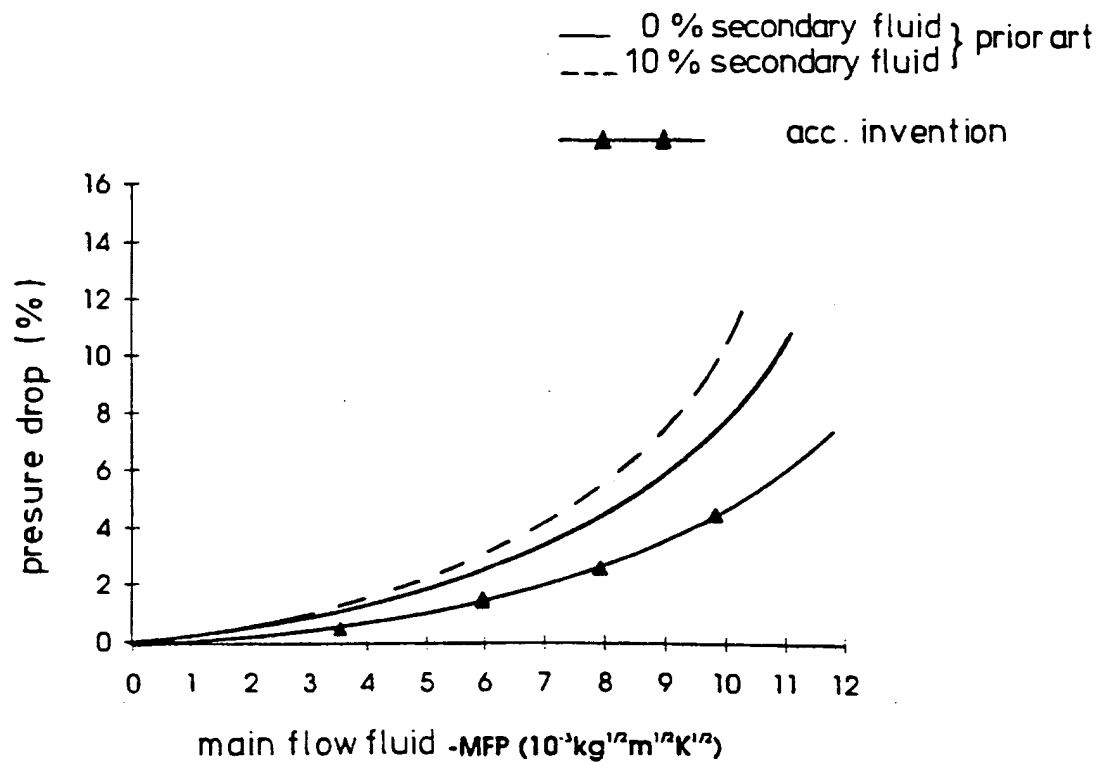
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1/2



2/2

fig-3



## INTERNATIONAL SEARCH REPORT

Int. onal Application No  
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According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,U,86 34 567 (TNO) 26 February 1987 see the whole document ---	1
A	US,A,5 245 977 (CHEN) 21 September 1993 see column 3, line 19 - column 5, line 58; figure 1 -----	1

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Information on patent family members

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DE-U-8634567	26-02-87	NL-A- 8603136	01-07-88
US-A-5245977	21-09-93	NONE	

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